



# THE THEORETICAL RATIONALE FOR TRACTION EFFORT EXPERIENCED WORKING PART OF THE CULTIVATOR FERTILIZER

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## ABSTRACT

*Traction effort required to move the working part of an experienced cultivator-fertilizer in the soil depends on many factors. These include friction coefficients of the soil, weight and humidity. In this article we are conduct a theoretical research, the purpose of which is to establish a relationship between the physicommechanical properties, parameters of the under development working part and the technological parameters of its work.*

**Keywords:** Traction, Tillage, Plowshares, Depth of Processing, Forward Speed.

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## 1. INTRODUCTION

Traction effort which is necessary to move the working part of an experienced cultivator-fertilizer in the soil depends on many factors. It is possible to refer physicommechanical characteristics of the soil sphere to them, constructive characteristic of working part and technical characteristics on working processing of the soil [1].

Physical and mechanical characteristics of the soil can be determined directly on the field. Coefficients of friction of the soil about measures or soils about the soil, volume weight and humidity are concerned to them. These indicators for characteristic soils can be defined also from references. Design data such as, width of taking of the working part, corners of solution and installation are appointed by the designer and depend on characteristics of the developed machine.

## 2. MATERIALS AND METHODS

Technological parameters include the working speed and depth of the working part [2,3]. They depend on the agrotechnical requirements and tillage and traction machine capabilities. In this work, a theoretical study is carried out, the purpose of which is to establish a mutual relationship between the physicommechanical properties, as instructive parameters of the working part being developed and the technological parameters of its work. Having such a connection, to operate them and to define their optimum a combination [4,5,6].

## 3. RESULTS AND DISCUSSION

Picture 1a shows the working part of the cultivator-fertilizer, which represents a bivalve flat-cut paw. The working part moves with the speed  $V$  and affects the soil sphere with the resultant power  $Q$ . The soil sweat resists the following power.

$R_1$  is the frontal sub time of unreformed soil layer;

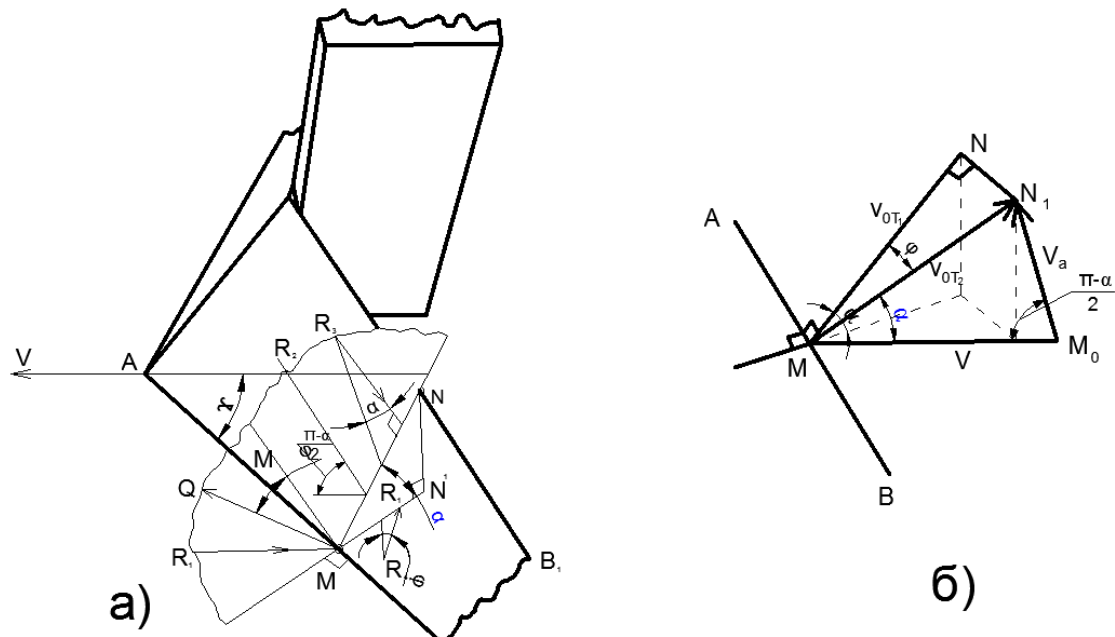
$R_2$  is the impulse of the head that will receive the soil under the inertial effects of the working part

$R_3$  is the reaction of the soil pliers on the edge of  $AA_1$ ,  $BB_1$ ;

$R_4$  is the reaction of the bottom of the furrow to the bottom of  $AA_1$ ,  $BB_1$  faces;

$F_3$  - soil resistance on the upper face  $AA_1$ ,  $BB_1$ .

$F_4$  - soil resistance at the sole of  $AA_1$ ,  $BB_1$  faces.



**Picture 1.** The interaction of an experienced working part of the cultivator-fertilizer with the soil

The soil particles move on the upper face along the line of the largest slope MN and, in the absence of friction, the normal pressure of the soil on the paw is directed along the line Nv. The presence of friction rejects it at an angle. The reaction of the soil is directed along R3 in the direction opposite to the possible displacement of the soil particle. An impulse or R2 also deviates in this direction, only not from the normal, but from the free-fall line.

The impulsive forces R2 arise at the initial moment of action of the working part on the soil, because at this time the inertia of which soil is broken, its particles get instantaneous accelerations and a certain absolute speed which does not coincide with a line.

Obviously, this scheme will be directed along the line of the absolute velocity of the particles, only in the opposite direction.

Sufficiently high probability we can assume that the particles will detach from the surface of the working part with the same speed with which it will be implemented into it. In reality, of course, they will not be equal, because at the expense of gas voids in the soil, and its compression and collapse, the speed of the soil will lag behind the speed of the working part. At the same time, this difference in comparison with absolute values may be insignificant. However, the context under consideration is not so much important their value as their directions.

As shown in picture 1b, in the absence of friction, the relative velocity of the soil particles will be directed along the MN line. The friction forces arising from between the soil particle and the metal of the working part over time  $t$  shifts the particle to point N1. In this case, the relative velocity of the particle will be:

$$v_{от2} \frac{V_{отл}}{C \cdot L \cdot \varphi} \quad (1)$$

The angle of elevation of the blade of the working parts blade is insignificant. Therefore, they can be equated:  $V_{от2} = V$

From mechanics it is known, according to the rule of the velocity triangle, the relative speed must be closed by the absolute speed. In this case, you can use the sine theorem:

$$V_a = V_{ot2} \frac{\sin M}{\sin M_0}. \quad (2)$$

The angle  $M_0$  is determined from the relationship:

$$M_0 = \pi - (N_1 + M)$$

From the equality  $V_{ot2} = V$ , it follows that in the triangle  $MN_0N_1$   $\angle N_1 = \angle M_0$

Therefore:

$$M_0 = \frac{\pi - \alpha}{2}. \quad (3)$$

Substituting (1) and (3) in (2) we get:

$$V_a = V \frac{\sin \alpha}{\cos \frac{\alpha}{2}}$$

$$V_a = 2V \sqrt{\frac{1 - \cos \alpha}{2}}. \quad (4)$$

From the expression (3) it follows that the absolute velocity of the soil particles  $V_a$  is directed at an angle  $(\pi - \alpha)/2$  to the direction of speed of the working part and in the direction coinciding with the directional movement. From this we can conclude that the impulsive forces that receive soil particles from the impact of the working part are also directed along the line  $V_a$ . Only sent in the opposite direction.

The resistance of the soil environment to the working part of the cultivator-fertilizer can be expressed to make up the equilibrium equation of all forces in the horizontal and vertical direction.

$$Q \cos \left[ \frac{\pi}{2} - (\alpha + \varphi) \right] = R_2 \cos \frac{\pi - \alpha}{2} \cos \left( \frac{\pi}{2} - \gamma \right) + R_3 \cos \left[ \frac{\pi}{2} - (\alpha + \varphi) \right] + R_4 \sin \varphi + \cos \left( \frac{\pi}{2} - \gamma \right)$$

$$Q \sin \left[ \frac{\pi}{2} - (\alpha + \varphi) \right] R_2 \sin \frac{\pi - \alpha}{2} \sin \left( \frac{\pi}{2} - \gamma \right) + R_3 \sin \left[ \frac{\pi}{2} - (\alpha + \varphi) \right] - R_4 \cos \varphi$$

$$Q \sin(\alpha + \varphi) = R_2 \sin \frac{\alpha}{2} \cdot \sin \gamma + R_3 \sin(\alpha + \varphi) + R_4 \sin \varphi + R_1 \sin \gamma$$

$$Q \cos(\alpha + \varphi) = R_2 \cos \frac{\alpha}{2} \cdot \cos \gamma + R_3 \cos(\alpha + \varphi) - R_4 \cos \varphi \quad (5)$$

In equations (5), the frontal support of the still unreformed formation in front of the working bodies can be expressed by the transverse area of the still unreformed formation through the working part:

$$R_1 = B \cdot h \cdot \sigma_{сж} \quad (6)$$

where:  $B$  - the width of the capture of one solution of the working part;

$h$  - tillage depth;

$\sigma_{сж}$  - ultimate soil resistance to compression.

In equality (c) the width of the capture of one solution of the paw depends on the length of the plowshare L:

$$R_1 = L \cdot \sin \gamma \cdot h \cdot \sigma_{\text{сж}} \quad (7)$$

The reaction of the bottom of the furrow on the lower sole of the working part is equal to:

$$R_4 = h \cdot B_{\tau} \cdot \sigma_{\text{сж}} \quad (8)$$

where: - the width of the lower image of the plowshare in contact with the soil.

The values from (7) and (8) are substituted into equation (5):

$$\begin{aligned} Q \sin(\alpha + \varphi) - R_2 \sin \frac{\alpha}{2} \cdot \sin \gamma - R_3 \sin(\alpha + \varphi) &= L \cdot B_{\tau} \sigma_{\text{сж}} \cdot \sin \varphi + L \cdot h \sin \gamma \sigma_{\text{сж}} \\ Q \cos(\alpha + \varphi) - R_2 \cos \frac{\alpha}{2} \cdot \cos \gamma - R_3 \cos(\alpha + \varphi) &= -L \cdot B_{\tau} \cdot \sigma_{\text{сж}} \end{aligned} \quad (9)$$

Let's transform in (9):

$$\begin{aligned} \frac{Q \sin(\alpha + \varphi) - R_2 \sin \frac{\alpha}{2} \cdot \sin \gamma - R_3 \sin(\alpha + \varphi)}{B_{\tau} \sin \varphi + h \sin^2 \gamma} &= \frac{Q \cos(\alpha + \varphi) - R_2 \cos \frac{\alpha}{2} \cdot \cos \gamma - R_3 \cos(\alpha + \varphi)}{-B_{\tau}}; \\ -Q B_{\tau} \sin(\alpha + \varphi) + R_2 B_{\tau} \sin \frac{\alpha}{2} \cdot \sin \gamma + R_3 B_{\tau} \sin(\alpha + \varphi) &= \\ Q B_{\tau} \cdot \sin \gamma \cdot \cos(\alpha + \varphi) - R_2 B_{\tau} \sin \varphi \cdot \cos \frac{\alpha}{2} \cdot \cos \gamma - R_3 B_{\tau} \cdot \sin \varphi \cdot \cos(\alpha + \varphi) + \\ + Q h \cdot \sin^2 \gamma \cdot \cos(\alpha + \varphi) - R_2 h \sin^2 \gamma \cdot \cos \frac{\alpha}{2} \cdot \cos \gamma - R_3 h \sin^2 \gamma \cdot \cos(\alpha + \varphi); \end{aligned}$$

Group all terms in Q, R2, R3:

$$Q[-B_{\tau} \sin(\alpha + \varphi) - B_{\tau} \varphi \cdot \cos(\alpha + \varphi) - h \cdot \sin^2 \gamma \cos(\alpha + \varphi)] = R_2$$

Accept the following notation:

$$A = (B_{\tau} \sin \varphi \cos(\alpha + \varphi) + h \sin^2 \gamma)$$

$$A = (B_{\tau} \sin \varphi + h \sin^2 \gamma);$$

$$C = B_{\tau} \sin(\alpha + \varphi) \quad (10)$$

In this case, the previous equation takes the form:

$$Q(C + A) = R_2$$

$$Q = \frac{R_2}{C+A} \quad (11)$$

The traction force R1, for its precise definition, will project the latter twice, at the beginning to the direction MN, and secondly to the direction of the translational speed of the working organ V:

$$P = Q \sin(\alpha + \varphi) \cdot \sin \gamma \quad (12)$$

To solve equation (12), it is necessary to substitute the value of Q in it. However, two forces remain unknown in (11) - R2 and R3.

The impulse R2, according to classical mechanics, is determined by the mass of the soil, which receives it and by the acceleration with which the soil element is excited [7].

$$R_2 = k \cdot m, \quad (13)$$

where:  $k$  – acceleration of the excited soil element

$m$  – the mass of the excited soil element..

Before the excitation is obtained, the initial velocity of the soil elements is zero,  $V_0 = 0$ . After the excitation of the soil element is obtained, the velocity  $V_a$  is acquired. They pass the width of the upper edge of the MN ploughshare in time:

$$t = B_i / V_{OT2},$$

where:  $B_i$  – width the upper edge of the plowshare;

$V_{OT2}$  – the relative velocity of the soil element will be equal:

$$u = \frac{V_a \cdot V_{OT2}}{B_i} = 2 \frac{V^2}{B_i} \cdot \sqrt{\frac{1 - \cos \alpha}{2}}. \quad (14)$$

For the considered time  $t$ , a soil layer with a mass passes through the upper edge of the plowshare edge:

$$m = L \cdot B_i \cdot h \cdot \rho, \quad (15)$$

where:  $h$  – tillage depth;

$\rho$  – soil weight.

Substituting (14) and (15) in (13) we get:

$$R_2 = 2Lh\rho V^2 \sqrt{\frac{1 - \cos \alpha}{2}}. \quad (16)$$

Oblique backwater formation, located on the upper face of the plowshare is characterized by its size:

$$R_3 = L_{B_i} \cdot h \cdot \rho \cdot q \cdot \cos(\alpha + \varphi), \quad (17)$$

where:  $q$  – acceleration of gravity.

Taking into account (16) and (17) from (11) we get:

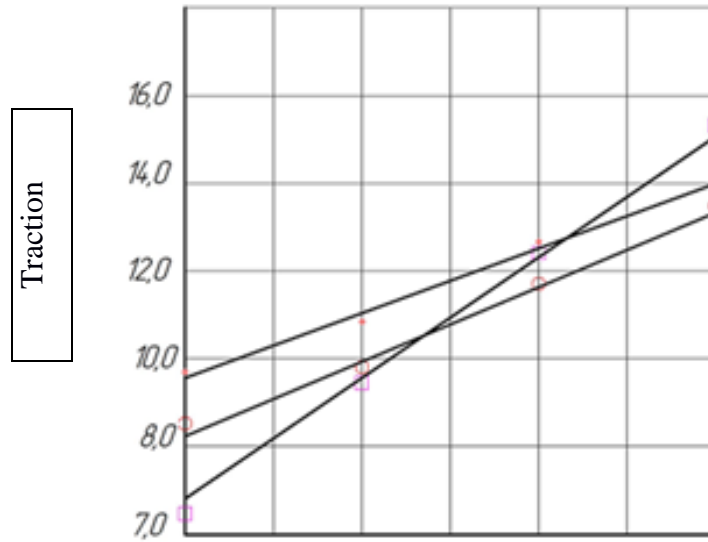
$$Q = Lh\rho \left[ \frac{2V^2 \sqrt{\frac{1 - \cos \alpha}{2}}}{A + C} \left( B_\tau \sin \frac{\alpha}{2} \sin \gamma + B \cos \frac{\alpha}{2} \cos \gamma \right) + L_{B_i} h \cdot \rho \cdot q \cdot \cos(\alpha + \varphi) \right] \quad (18)$$

In this case, equation (12) takes the form:

$$P = Lh\rho \cdot \sin(\alpha + \varphi) \sin \gamma \quad (20)$$

**Table 1** The dependence of the traction effort of the tillage working part on the length of the plowshare, the depth of treatment and the translational speed

№	Ploughshare length L(m)	Traction P(Kr)	Processing depth h (m)	Traction P(Kr)	Speed V(M/c)	Traction P(Kr)
1	0,1	3,22	0,06	7,39	1,8	9,72
2	0,12	9,86	0,08	9,86	2,0	10,88
3	0,14	11,5	0,1	12,33	2,2	12,33
4	0,16	13,15	0,12	14,79	2,4	13,58
5	0,18	14,79	0,14	17,26	2,6	15,1



**Picture 2** Dependences of traction effort of an experienced soil-cultivating working part on the length of the plowshare, the depth of treatment and the translational speed

We will check the theoretical result by calculating the pulling force of the working part using equation (20). The numerical values of the are taken from the literature [8,9].

$h = 0.1\text{ m}$  - tillage depth;

$L = 0.15\text{ m}$  - the length of the share;

$\alpha = 25^\circ$  - cutting angle, plowshare angle;

$V = 8\text{ km/h} = 2.22\text{ m/s}$  - the translational speed of the working part;

$\gamma = 45^\circ$  is the angle of the half-solution of the working part;

$B_i = 0.1\text{ m}$  –width of the upper edge of the plowshare;

$B_\tau = 0.01\text{ m}$  – the width of the lower edge of the plowshare in contact with soil;

$\rho = 10^3 \frac{\text{Kr}}{\text{cm}^3}$  – Bulk weight of the soil.

At the beginning, we calculate the values of the constant values A, B, C:

$$A = (0,01 \cdot \sin 30^\circ \cos 55^\circ + 0,1 \sin^2 45^\circ) = 0,0775;$$

$$B = (0,01 \sin 30^\circ + 0,1 \sin 45^\circ) = 0,099;$$

$$C = 0,01 \sin 55^\circ = 0,082.$$

Substitute the values of the components of the equation (20)

$$\begin{aligned} P &= 0,15 \cdot 0,1 \cdot 10^3 \cdot 0,81 \\ &\cdot 0,7 \left[ \frac{2 \cdot 4,43 \cdot 0,3}{1,41 \cdot 0,16} (0,01 \cdot 0,216 \cdot 0,7 + 0,099 \cdot 0,97 \cdot 0,7) + 0,1 \cdot 9,81 \cdot 0,57 \right] \\ &= 12,33 \text{ кГ} \end{aligned}$$

#### 4. CONCLUSION

- The calculation showed that the traction force of the working part with the adopted technological and design parameters is equal to  $P = 12.33 \text{ kg}$ , which fully corresponds to a certain result.
- According to the structure and nature of equation (20), it can also be noted that the traction force of the working part is directly proportional to the length of the plowshare, the depth of processing and the angles of cutting and solution of the paw, as well as the square of the translational speed.
- The calculated values of the traction effort are presented in Table 1 and illustrated in Picture 1. At the next stage of the study, the results obtained should be checked in laboratory experiments, by pulling an experienced working part in the soil channel and by dynamometer traction.



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